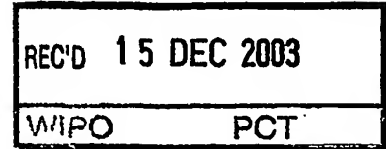


PCT/NZ03/00251



## CERTIFICATE

This certificate is issued in support of an application for Patent registration in a country outside New Zealand pursuant to the Patents Act 1953 and the Regulations thereunder.

I hereby certify that annexed is a true copy of the Provisional Specification as filed on 11 November 2002 with an application for Letters Patent number 522552 made by Muthuvetpillai Jegastheeson.

Dated 25 November 2003.

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**IMPROVEMENTS IN ONE-WAY CLUTCHES**

I, Muthuvetpillai Jegastheeson, of 1/116 Campbell Road, Onehunga,  
Auckland 1006, New Zealand,

*do hereby declare this invention to be described in the following  
statement:*

## TITLE     **Improvements in one-way clutches.**

### FIELD

This invention relates to mechanical coupling devices known as "free-wheeling clutches" or "one-way clutches"; devices including mechanisms capable of applying a torque between  
5 apposed parts in order to transmit rotation in one direction but not in the other direction.

### BACKGROUND

Free-wheeling or one-way clutches are used in mechanical engineering applications for converting reciprocating motion to rotational motion. For example, bicycle chain drives have  
10 a ratchet-based one-way clutch serving to prevent the chain and cranks being turned when the rider is coasting. Another of many applications is in machines for making electric energy in a dynamo driven by to-and-fro wave motion. A one-way clutch can be regarded as a mechanical equivalent to an electrical diode - a device for transmitting power in only one direction.

15 Existing one-way clutches rely on one or another mechanism to lock the driving and driven parts together when relative motion between the parts changes from a free-wheel direction to a driven direction. Some locking mechanisms are of the ratchet type, with pawls (or struts) and pockets. This class produces a clicking noise during free-wheeling and exhibit backlash, but when engaged the pawls provide an effective direct coupling of torque without  
20 damage to materials. Other locking mechanisms involve a wedging action between either a strut/sprag or a roller which enters and becomes locked within a tapered recess when engaged. Usually a replicated set of locking mechanisms are provided in a circumferential array. While these one-way clutches are relatively noiseless and have little backlash, the wedging action inherently applies a significant strain between the movable part(s) and a  
25 small surface area of the adjacent slot, amplified by the tangent of the taper and by excessive torque. Hence this type of one-way clutch typically has a short life. Reverting to ratchet types, there is a particular class of radially oriented, planar one-way clutches employing struts to reversibly connect between the parts.

Existing one-way clutches of the pawl type have a certain amount of reverse motion (also known as backlash) before the parts become locked together. By the time positive engagement occurs some momentum may build up and the impulse occurring at the time of contact may be harmful. It may shock the materials to such an extent that fatigue occurs (if only after a number of cycles), hence the clutch parts must be made strong enough to resist failure. The mechanisms including a wedging action with rollers, sprags, or balls that significantly magnifies the force per unit area involved. Vibration or noise are other likely problems. If resilient members are used to buffer the impacts, unexpected resonances may occur and the resilient material will fail in time.

## PROBLEM TO BE SOLVED

The problem to be solved can be stated as "to provide a one-way clutch utilising positive engagement yet with reduced backlash and free-wheeling losses together with an enhanced operating life while handling useful loads". A reliable mechanical equivalent to a "perfect diode" is sought.

## OBJECT

It is an object of this invention to provide an improved one-way clutch, or at least to provide the public with a useful choice.

## STATEMENT OF INVENTION

In a first broad aspect this invention provides a one-way clutch for reversibly coupling a first shaft to a second shaft when one shaft is turned in a first ("engaging") direction relative to the second shaft but not providing coupling when turned in the opposite ("coasting") direction; the mechanism thereof including (a) a first support frame or ring, held upon the first shaft, bearing a plurality of male (or pawl/strut) members on a first end face, (b) a second support frame or ring held upon the second shaft and held adjacent to the first ring, bearing a plurality of female members (or pockets) each capable of reversibly coupling with an apposed pawl on a second end face, *wherein* the number of male members is  $n$  and the number of female members is  $m$ , so that the male members and female members are

arranged in a "vernier fashion" (as herein defined) with a high chance that at any moment one male member is closely adjacent in a rotational sense to one female member, and so that the amount of movement or backlash of one shaft in relation to the other that occurs before a male member can firmly engage a female member on commencing rotation in the engaging direction is less than the case when  $m = n$ .

Preferably  $|m - n|$  is greater than 1 so that when the one-way clutch is in an engaged mode the resulting set of more than 1 firmly engaged members is located in a symmetrical manner about the axis of the or each shaft.

Preferably the male member is a pawl articulated from the end face of the first ring.

65 Preferably the female member is a pocket formed within the end face of the second ring.

In a second broad aspect the invention provides a one-way clutch having a directionally dependent biasing means applied to the or each male member, so that the or each male member is caused to extend towards a corresponding pocket when the relative movement of the first and second rings of the one-way clutch occurs in a first direction, but not when movement is in a second, or free-wheeling direction.

Preferably the male member has a supporting face concentric about a pivotal axis mounting aperture and capable of transmitting a load to a matching base area upon the end face of the first ring, an elongated beam capable of withstanding a compressive force and of supporting a load-bearing face upon the end of the beam.

75 Preferably the male member is held in pivotal alignment in relation to the matching base area by a mounting fastener passed through the mounting aperture.

Preferably the male member is capable of being caused to pivot about the mounting fastener in order to alternate from time to time between an engaged, protruding state, and a disengaged, concealed state.

80 Preferably the directionally dependent biasing means comprises a direction-dependent drag applied to a portion of a projection mounted so as to project from each male member in proximity to the second support so that relative rotation of the rings of the one-way clutch in the first or engaging direction tends to cause the male member to rotate outwards about the pivotal mount.

85 Preferably the directionally dependent biasing means comprises a caster wheel mounted upon the male member and in rolling contact with the apposing ring and in a direction such

that motion in the first direction will tend to cause the wheel to drag outwards and pull the male member outwards; whereas motion in the second direction will tend to cause the male member to be retracted.

- 90 Alternatively the directionally dependent biasing means comprises a magnetically susceptible mass mounted from the male member so that the mass is either pulled or pushed by slanting poles impressed into an adjacent surface of the second frame support, depending on the direction of rotational movement.

A third preferred directionally dependent biasing means comprises viscous material (such as  
95 grease) over a pattern of spiralling ribs impressed into an adjacent surface of the second frame support.

A fourth preferred biasing means comprises a tracking contact arm sliding on an adjacent surface of the second frame support and capable of being directed by a pattern of spiralling ribs impressed into the surface of the second frame support.

- 100 A fifth preferred biasing means comprises a spring or the like applying an outwards push; the action of the spring being opposed by a directionally dependent biasing means during relative movement in the first direction.

In a third broad aspect the invention provides a geared one-way clutch having little backlash and a novel engagement means, in which a reversible coupling and decoupling is effected  
105 within a gear coupling of the type where the transmission of power is not effectively reversible; the coupling "seizing" if driven in reverse.

One preferred gear coupling is a worm screw driving a worm wheel.

- Preferably the geared one-way clutch comprises a drive shaft and a driven shaft, the driven shaft being connected to a gearbox frame and to a worm wheel, the drive shaft being  
110 connected to a worm wheel and a first gear of a gear train having one or more intermediate gear wheels, the gear train including a controlled amount of backlash; the last gear of the gear train driving the worm screw, the gear train having a ratio which is equal to the ratio of the worm screw and worm wheel so that the worm screw may be turned at a rate capable of maintaining the worm screw in step with the worm wheel.

- 115 Preferably the gears including the worm are mounted on stub axles supported by the frame, except that the first gear is supported on the incoming drive shaft.

Preferably the geared one-way clutch is set up (in a phase sense) so that when the drive

shaft is driven in a coasting direction and all backlash is taken up, the worm screw makes minimal contact with the worm wheel during motion, so that substantially no frictional loss occurs.

Preferably the geared one-way clutch is set up (in a phase sense) so that when the drive shaft is driven in an engaging direction and all backlash is taken up, the worm screw makes rubbing contact with the worm wheel so that substantial friction occurs and so that the mechanism becomes locked together, and the geared one-way clutch becomes engaged.

125 Preferably the backlash is provided by provision of a loose dog clutch between the driving shaft and the first gear of the gear train.

## PREFERRED EMBODIMENT

The description of the invention to be provided herein is given purely by way of example and is not to be taken in any way as limiting the scope or extent of the invention.

## 130 DRAWINGS

Fig 1: is a diagram showing part of a one-way clutch according to Examples A and B, in the disengaged mode.

Fig 2: is a diagram showing part of the one-way clutch of Fig 1, in the engaged mode.

135 Fig 3: is a diagram showing the interlockable components of a complete one-way clutch according to Examples A and B, in the disengaged mode.

Fig 4: is a diagram of a caster system for encouraging engagement and free-wheeling (when appropriate) of radially directed pawls (here the pawls are of the type shown in Fig 7).

Fig 5: is a diagram of a pawl and a corresponding pocket.

140 Fig 6: is a diagram of a caster system (6A) and of an analogous magnetic system (6B) for dragging each pawl into or away from an engagement position according to relative rotational movement of the parts of the clutch.

Fig 7: is a diagram of a pawl with a caster wheel beneath.

Fig 8: is a diagram of a gear train and worm inside a frame.

145 Fig 9: is a perspective view of the gear train and worm.

Fig 10: is another perspective view of the gear train and worm.

Fig 11: is a diagram showing a first face plate having 10 "engagement areas" and a second face plate having 9 "engagement areas", and an overlay of the two showing the single (at most) possible point of coincidence.

150 Fig 12: is a diagram showing a first face plate having 16 "engagement areas" and a second face plate having 20 "engagement areas", and an overlay of the two showing the four possible points of coincidence.

155 This invention comprises, separately or in combination, (A) a "vernier" arrangement of mating pawls and pockets, (figs 1-3, 11-12) and (B) systems for directing pawls into or out of engagement with sockets according to the direction of rotation (figs 1-7); the invention also comprises (C) a further solution to the problem to be solved (in figures 8-10), making use of a gear train for driving a worm screw in one or another phase relationship to a worm gear, within a frame.

## EXAMPLE A

160 Example A comprises a first way to improve one-way clutches. In principle, this aspect of the invention reduces the backlash or dead motion effect seen in one-way clutches of the types relying on mating pawls and pockets (or the like) by providing a "vernier" relationship between pawls and pockets rather than a 1:1 correspondence. For example, there might be n pockets and m pawls(struts, or the like) as suggested diagrammatically in Figs 11 and 12. Fig  
165 11 shows 9 pockets (or pawls) at 1100, and 10 pawls (or pockets) in the "ring", 1101. In the overlay of the apposing second ring, 1102, the single engaged pawl in pocket is at 1103. The backlash of this example is reduced from  $360/10 = 36$  degrees of rotation to  $[360/10 - 360/9] = 4$  degrees of rotation or a 9 times improvement.. Fig 12 shows a multi-engagement alternative. Here, m may be 20 (ring 1201) and n (in ring 1200) may be 19 (for a single pawl-pocket match), 18 (for a double pawl-pocket match), or 16 as illustrated (for a quadruple  
170 pawl-pocket match in 1202, having 2.5 degrees of rotational backlash). There is no particular constraint on the number m. Fig 12 shows four sites of simultaneous engagement at 1203A, 1203B, 1203C, and 1203D in the overlay 1202. If there are 20 pawls and 19, not 20 pockets, the backlash of the present invention is reduced from  $360/20 = 18$  degrees of rotation to  
175  $[360/20 - 360/19]$  or about 0.947 degrees of rotation, assuming of course that operating conditions allow the pawls to emerge instantly on reversal of rotation. In that case a single



pawl/pocket engagement occurs. It may be preferable to have an engagement site symmetrically on each side of the axis of rotation by having more than one sets of pawl-pocket matches placed symmetrically about the shaft so that eccentric loads on bearings, for example, are reduced. In many practical embodiments it may be preferable to accept doubling or more of the substantially reduced backlash provided by this invention for the sake of symmetry of loading. Figs 1-3 show practical examples of pawl and pocket type one-way clutches embodying the vernier principle. In Fig 1, note how pockets 105A, 105B, and 105C are out of line with adjacent pawls.

Preferably any one pawl should be capable of withstanding a substantial load for this invention, because only one or a small number of the pawls (struts) are simultaneously engaged. This Example is clearly also applicable to many forms of existing one-way clutches, in particular those having a radial array of struts (or pawls) and pockets. In relation to noise and vibration, these are minimised by use of the "vernier" approach to pawl and pocket spacing. Clicking noises are no longer created simultaneously at all sets of pawl and pocket in the clutch; clicks are now spaced apart from each other. Because of the vernier effect the clicks will occur at a multiple of the original frequency. Also in relation to noise and vibration when the one-way clutch comes into action, the amplitude of related noise is reduced because of reduced backlash - the reverse momentum of rotating parts is not able to build up to as great an amount before the one-way clutch comes into action.

## EXAMPLE B

Example B relates to means to cause the pawls to protrude and seek corresponding pockets when the one-way clutch is driven in a direction intended to result in locking. This Example includes an improved pawl shape as shown in Fig 5, where a pawl 103 is comprised of an end face 503 which reaches into a nearby pocket in the other ring of the one-way clutch, a body 504, providing a substantially incompressible length to the pawl, and a rounded face 502 which is concentric about a mounting hole 501 about which the pawl may pivot in order to change between an engaged, protruding state, and a disengaged, concealed state. During engagement, thrust is carried between the end face 503 and the rounded face 502. The hole face 502 forms a joint or hinge with a corresponding curved groove in the ring 102 of the one-way clutch. The height of the pawl may be varied according to application; longer faces can safely carry more power but a greater mass is slower to move. Optionally the end face 503 is sloped in order to secure a positive engagement within the pocket. Preferably the attitude of the end face is such that it makes contact with substantially the whole face 506 of

the pocket formed in the other ring 101 of the one-way clutch. That face 506 may be made slightly re-entrant.

The retaining bolt 104 (see the cap screws in figs 1 or 7) is able to be replaced by simply extending the encompassing joint further around the rounded face of the pawl, and using a  
215 circlip to prevent the pawls from flying or dropping out, but individual retaining bolts allow easier assembly and maintenance.

It will be appreciated that this design of pawl is usefully, but not necessarily linked to use of the vernier placement of pawl-pocket engagement sites as described in Example 1. The vernier system can be used with the radial struts (or the like) of prior art inventions, and/or  
220 those radial struts can be replaced with these sturdier pawls.

Means to make the end faces of the pawls 103 tend to push out and seek engagement with passing pockets 105 are desired, so that the one-way clutch can be switched between an engaged and a disengaged mode according to the driven direction. Springs are usually used in the prior art to provide a constant bias but problems associated with the use of direction-  
225 insensitive bias means, common to most one-way clutches, include eventual wear of rubbing parts, and a relatively loud clicking noise arising whenever the one-way clutch is being operated in a free-wheeling direction so that the pawl edges pass over the pocket edges in the anti-engagement direction and drop into the pockets.

Avoidance of the use of springs or the like to bias the pawls (struts or the like) into  
230 engagement may be an advantage in some instances. Therefore, in Example B we propose the use of directionally dependent biasing devices, such as individual caster wheels to cause each of the pawls to pivot about its pivotal axis. See Figs 4, 6, and 7. One wheel 401 may be attached at the end of a beam 402 to each and every pawl (see Fig 6A, 7) at an oblique angle to the movement of the underlying surface 101 so that friction of the wheel against  
235 the surface drags the beam 402 to one side or the other and provides a continuous torque to the pawl in either an emerging direction, or a retreating direction, depending on relative motion (if any) of the two rings 101, 102 of the one-way clutch. This method may benefit by due attention to wear between the wheel and the surface 101. The angle of deflection should be enough to initiate pawl movement when required, but not so much as to cause  
240 undue wear during free-wheeling.

Another directionally dependent biasing device (see Fig 6B) is a mass of magnetically soft iron 602 on the end of the beam 601, which is either pulled out or pushed in by a dragging

effect from a repeating pattern of sloping magnetic poles (603, 603') imprinted on a surface below. The poles can easily be made by magnetising (for example) a hard ferrite collar, or a magnetically hard steel with a suitably shaped wound polepiece (perhaps also making use of the Curie transition temperature). This approach has the advantage that there is no actual frictional contact between each iron mass and the moving surface below the mass. In Fig 6, the pockets in 101 are not shown. They are on the reverse side. A viscous material (such as grease) in combination with a pattern of spiralling ribs may work in a similar way, although a long period of free-wheeling would heat the viscous material so that it would exert less drag. A physical probe may alternatively be used to trace the outlines of the pattern of ribs and drag each pawl accordingly. There are a number of other solutions to providing a direction-dependent bias any of which will be clear to one versed in the art. For example, a spring or the like may normally apply an outwards push but the action of the spring is opposed by a directionally dependent biasing means during relative movement in the first direction, so that the one-way clutch has a backup biasing means.

Action of the clutch is shown in Figs 1 - 4. Figs 1 and 3 show the clutch in a coasting or free-wheeling mode, allowing relative movement between ring 101 and ring 102, and Fig 2 shows the clutch in an engaged mode with pawl 103C carrying thrust, and no relative movement between the ring faces. Fig 4 shows the position of a set of caster wheels 401A..401D during engagement. Here, 401B is connected to an engaged pawl and the others are not engaged. Other components shown in Figs 1-4 are: pockets 105A, 105B and 105C and a second pawl in Fig 1, pawls 103A, 103B and 103D in Fig 2, and caster wheels 301 and 302 in Fig 3 (see also Fig 7).

## EXAMPLE C

This example of a one-way clutch has a different underlying principle for accomplishing the solution to the problem. In this Example, thrust is not carried by colliding parts when the two parts of the clutch come into engagement. This Example (see Figs 8, 9, and 10) makes use of a braking effect seen in some gear couplings where the transmission of power is not effectively reversible, such as but not limited to the case of worms driving worm wheels. A gear train is capable of driving a worm screw in either a first (free, without contact) or a second (with contact and friction) phase relationship to a worm gear, but otherwise at the same rate. The phase relationship is set by means of a controlled amount of backlash (provided at the connection between the drive shaft 801 and the first driven gear 706 at 707-707A) in the drive between the input shaft and the first gear of the gear train. Fig 8 shows a

side view of the invention, including a train of gears and a frame, including:

1. A drive shaft, 801, within bearings 802
2. A driven shaft 803 within bearings 804, connected to a frame 806 at 807,
3. A frame, encompassing a worm gear 704 (704 is supported on the input shaft 801) and  
280 holding a driven worm screw 705,
4. A first spur gear 706 around the drive shaft,
5. A coupling 707 between the spur gear and the drive shaft having inherent backlash 707A
6. A gear train, 708, 710, 711, and 712 held on the frame 703, coupling the spur gear and the  
worm screw, which is driven by the gear train at a rate which matches the worm ratio.  
285 The illustration shows two idler shafts and the second one drives a bevel gear 711 - 712.  
The gear train may be helical or other types instead of straight-cut gears, as is well  
known in the art.

All the gears including the worm are mounted on stub axles supported by the frame, except  
that the first gear is supported on the incoming drive shaft. When the assembly is being  
290 driven in a first direction and the clutch is free-wheeling, not driving, the driven gear train  
makes the worm rotate at a speed (and in a phase) which results in the thread of the turning  
worm screw 705 passing between the teeth of the worm wheel 704 with substantially no  
rubbing contact or resulting friction. In effect the worm 705 screws itself around the gear 704  
at exactly the rate of turning of the frame, relative to the input shaft. (The proper phase will  
295 be set during construction or installation). In this free-wheeling direction the gears turn  
freely, the frame is not forced to rotate, and there is no coupling between the input shaft  
801 and the output shaft 803.

When the assembly is being driven in a second (opposite) direction and the clutch is now  
intended to serve as a coupling between driving and driven shafts, the backlash device 707A  
300 built into the mounting of the spur gear 706 (together with any incidental backlash in the  
driven gear train) changes the speed of the worm while the backlash is interrupting the  
worm drive so that when the worm is again driven it will tend to rotate at the same speed  
but in a phase which results in one side of the thread of the worm rubbing against the teeth  
of the worm wheel with significant friction. Given the commonly exhibited self-locking  
305 effect, the locked pair causes the clutch to transmit power from the driving shaft 501 via the  
frame 503 to the driven shaft 502. (Please note that the diagrams of Figs 8, 9, and 10 are

not intended to show correct ratios, they serve to illustrate the concept). A weight 805 may be used on the frame to provide dynamic balance to the assembly. During a change in state, there may be a transfer of momentum from the worm screw to the worm gear.

310 This apparently complex mechanism has the purpose of avoiding concentrated loadings (together with impact components), such as those that occur in wedging or pawl-based one-way clutches. Instead, the loading is spread over the larger contact area, the "effective face width" between the worm thread and the worm gear. The usual lubricated rubbing surfaces should make rubbing contact only during transitional periods.

315 In the event of a variation in speed of drive, rotational inertia within the gear train and worm is coupled back into the drive through the worm gear.

This device may be particularly suited to low-speed, high-power applications.

## VARIATIONS

The examples shown here are purely illustrative. One-way clutches may be used in a great  
320 variety of applications each of which has a particular set of requirements, such as low noise, high reliability, suited to high or low speeds, and/or coupling or not of high shaft torques. A variety of new applications may be made feasible by improved performance.

## COMMERCIAL BENEFITS or ADVANTAGES

Low backlash is provided by means of the vernier alignment of pawls and pockets, so that a  
325 "first available pawl-pocket" alignment occurs with significantly less angular movement than in prior art devices. (For example, use of a 19:20 relationship instead of a 20:20 relationship reduces the backlash by just over 20 times).

Low noise is provided by means of the vernier alignment of pawls and pockets, so that the clicking as pawls run over pockets in the free-wheeling mode (if biased to do so) is  
330 asynchronous and at a significantly higher rate.

Low noise is provided by means of the directionally dependent bias system of steering the pawls into or out of the pockets, so that they do not run over the edges of the pockets and drop into the pockets when turning in the free-wheeling direction.

335 High reliability is provided by low or substantially absent backlash, so that development of reverse momentum and resulting impact force is significantly less.

High reliability is provided by avoidance of the wedging of parts against each other involving a high amount of locally applied force, so avoiding deterioration of materials and a short service life.

340 The geared system provides the same advantages, namely minimal free-wheeling losses, is positively driven when in the engaged mode, and is a non-wedging type of one-way clutch.

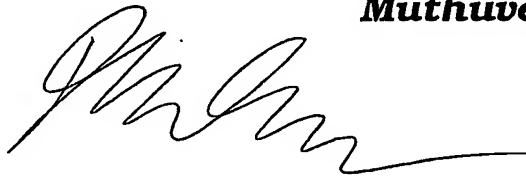
Finally, it will be understood that the scope of this invention as described and/or illustrated herein is not limited to the specified embodiments. Those of skill will appreciate that various modifications, additions, known equivalents, and substitutions are possible without departing from the scope and spirit of the invention as set forth.

345

**Ensor and Associates**

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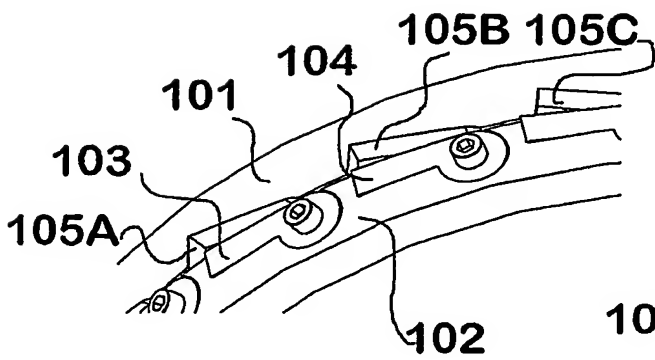
**Muthuvetpillai Jegatheeson**



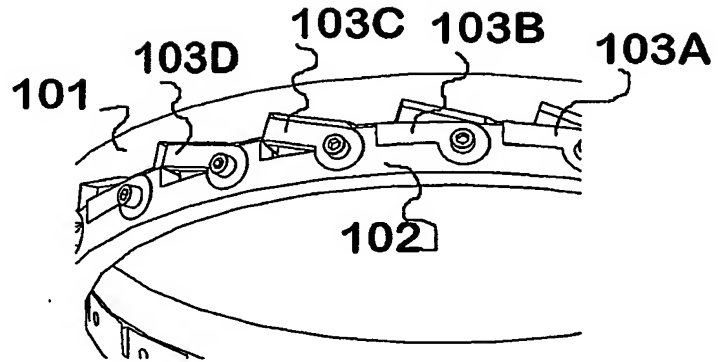
## ABSTRACT

One-way clutches are provided, having a "vernier" arrangement of mating  
350 pawls/sprags and pockets which has the effect of reducing the amount of  
rotation (backlash) before any pawl and pocket become aligned and engage,  
and/or rotationally sensitive mechanisms (replacing biasing springs) for  
directing pawls into or out of engagement with sockets according to the  
direction of rotation so that the pawls are withdrawn during coasting.

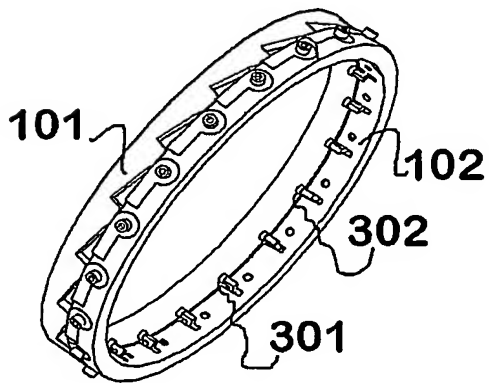
355 The invention also includes a gear train for driving a worm screw in one or  
another phase relationship to a worm gear, within a frame connected to an  
output shaft. Backlash in or preceding the gear train places the worm drive in  
either a high-friction mode in a first direction caused by the worm screw rubbing  
against the worm gear, (when the one-way clutch is engaged) or a low-friction  
360 mode when driven in an opposite direction (when the one-way clutch is in a  
coasting mode).



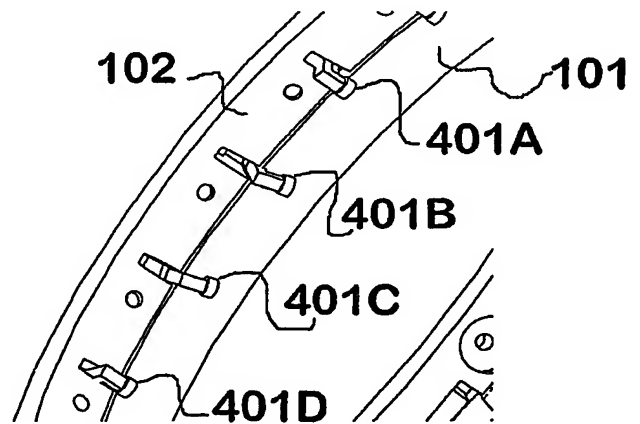
**fig 1**



**fig 2**

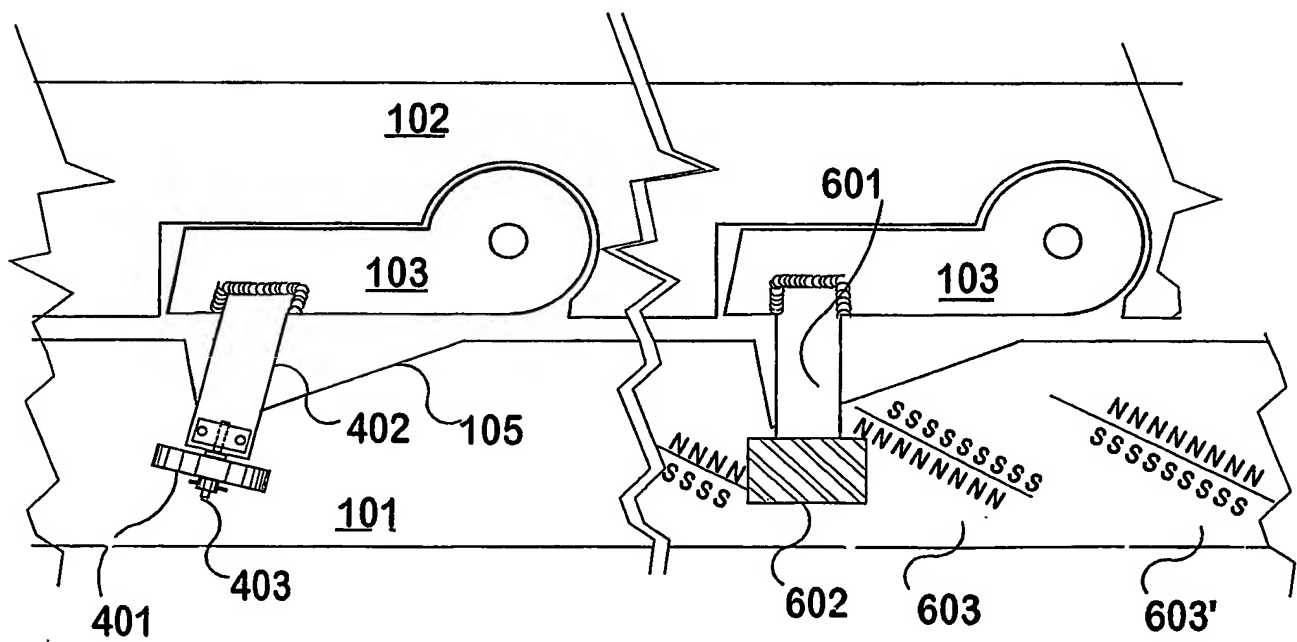
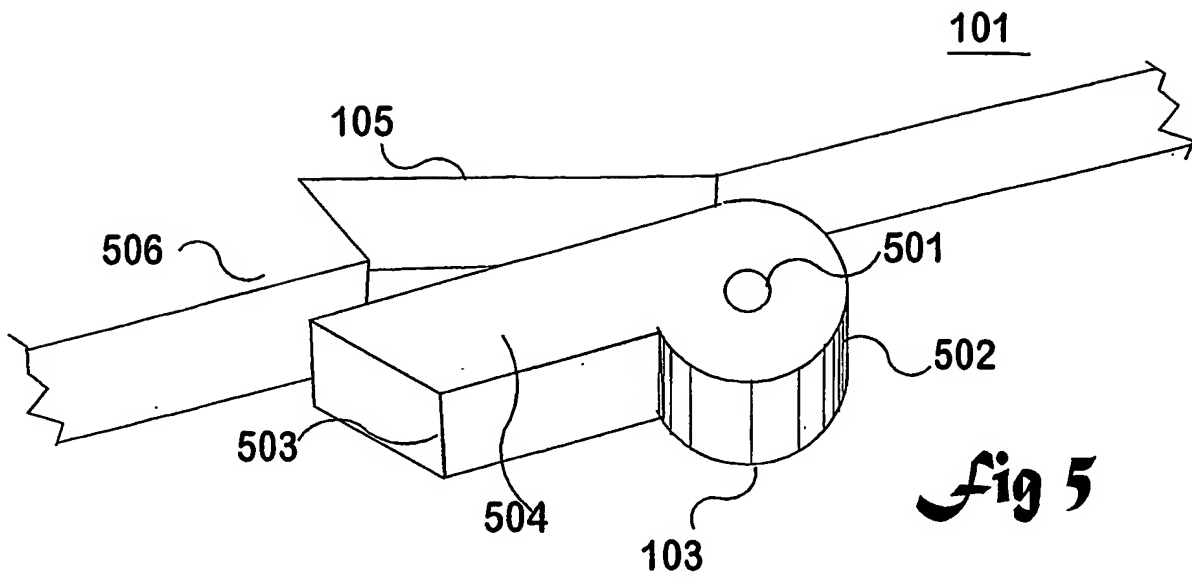


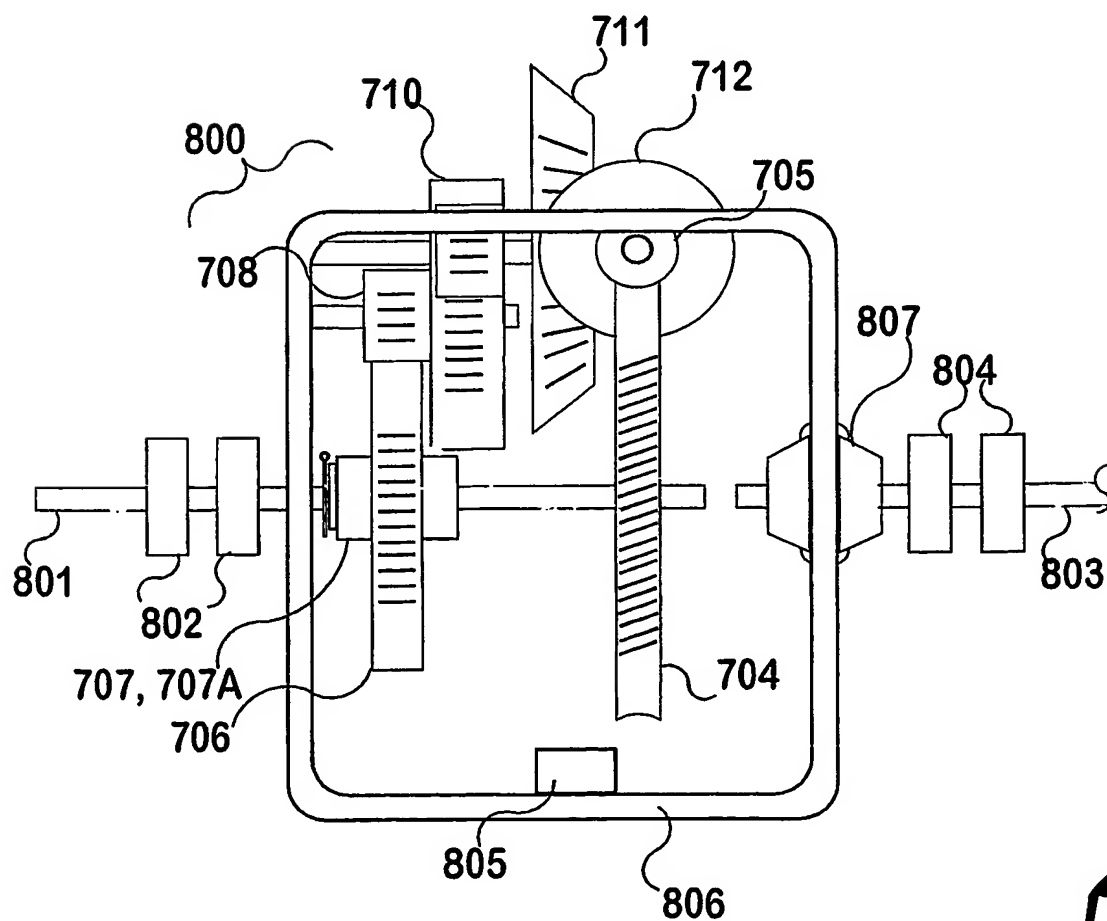
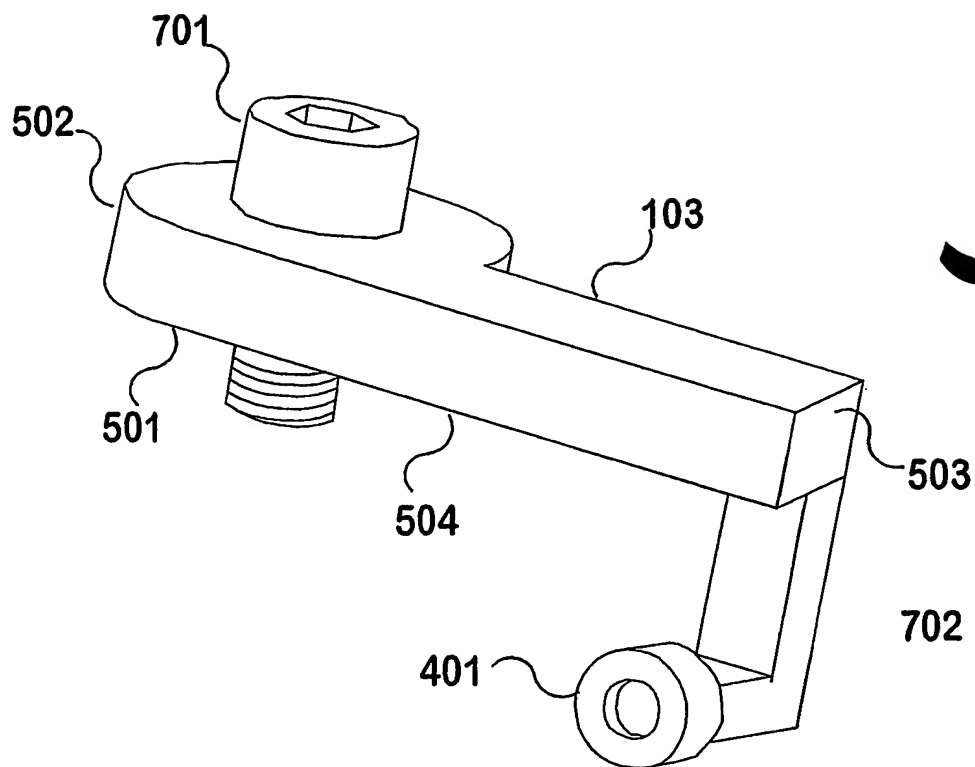
**fig 3**



**fig 4**







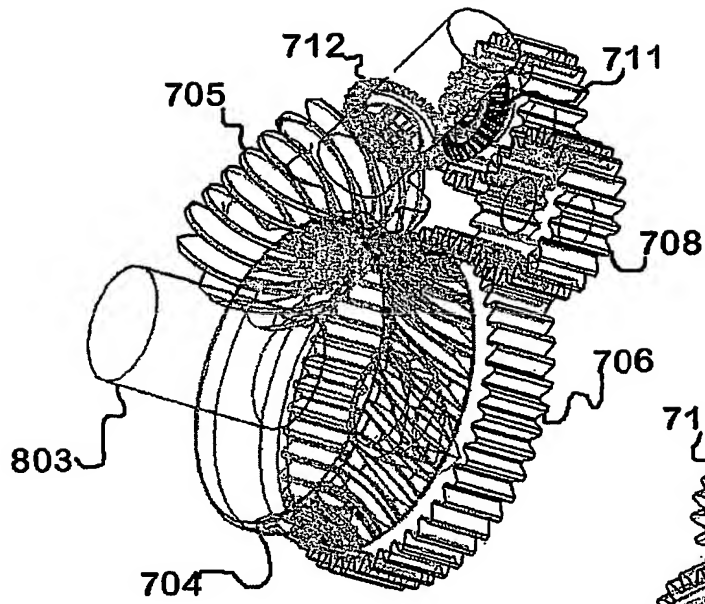
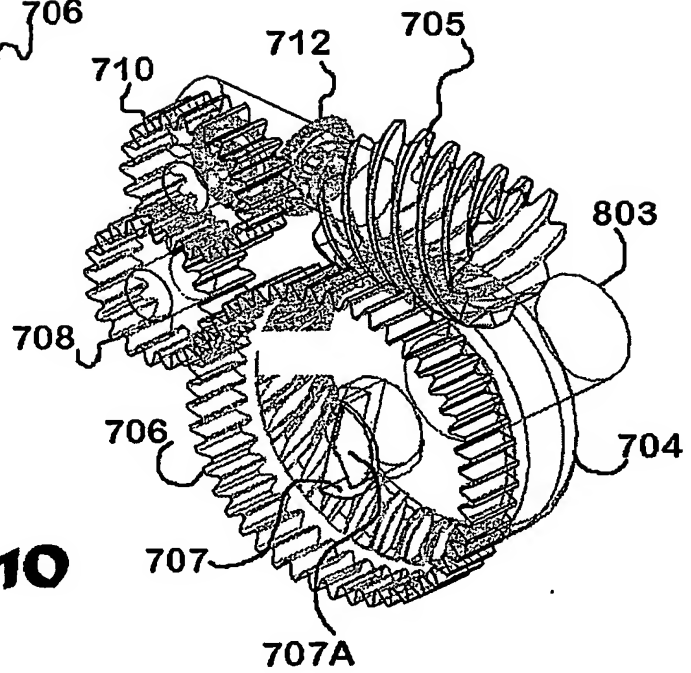
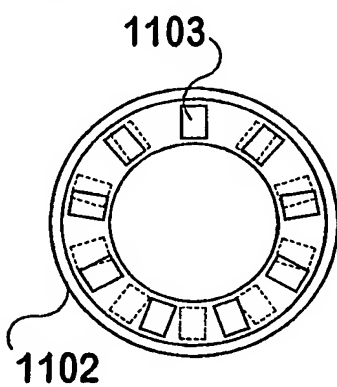
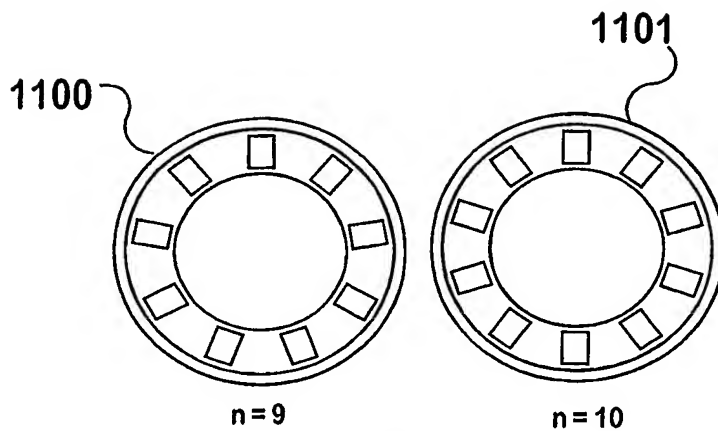
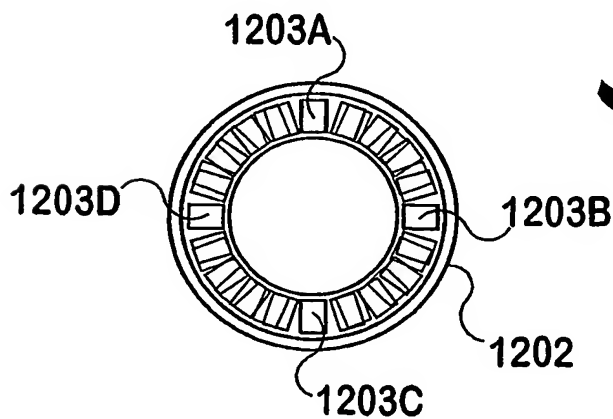
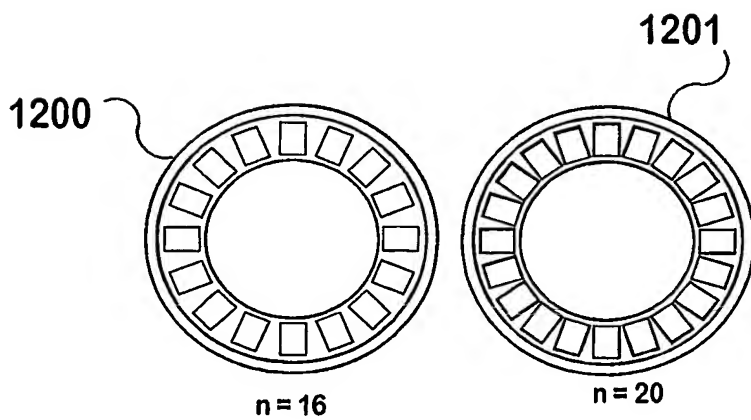


Fig 10





**Fig 11**



**Fig 12**

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